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AN AUTOMATIC RADIOTELEGRAPH TRANSLATOR AND TRANSCRIBER FOR MANUALLY SENT MORSE.

William Everett Althoff

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THESIS

AN AUTOMATIC RADIOTELEGRAPH TRANSLATOR AND TRANSCRIBER FOR MANUALLY SENT MORSE

by

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Thesis Advisor: S. Jauregui Jr.

December 1973

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An Automatic Radiotelegraph Translater
and
Transcriber for Manually Sent Morse

by

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Lieutenant, United States Naval Reserve
B.S., Newark College of Engineering, 1969

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
December 1973

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ABSTRACT

The problem of translating and transcribing manual morse automatically had been considered as early as 1958. The construction, evaluation, and subsequent modification of just such a device is considered here.

The nature of the problem is discussed including the basic detection problem encountered with manual morse. An explanation of the theory of operation of the device follows with a block diagram and a short description of each block. The third section discusses the tests, evaluation and modifications including operation in the minimum signal to noise ratio and code speed tracking capability. Areas for further development are next considered which include an automatic recalibration scheme and the use of "read only memories" in the decoding section. The conclusions make up the last section which considers the effectiveness, costs and limitations.

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I. INTRODUCTION

In recent years the cost of man power in the armed forces has increased at an unprecedented pace. At the same time there is much apprehension on the part of Congress and the people for appropriation of funds for larger defense budgets. The end result of these two forces is evident. There must be a cut in man power but the same level of effectiveness should be maintained. Devices and systems must be developed to fill the gap that the man power cut leaves. Automation of manual tasks seems a reasonable answer.

The area dealt with here is communications and more specifically manual morse. There is still a large need for copying manual morse in the armed forces. The current method for transcribing this signal is still by operator ear. If there existed a device that was able to perform the operation of the human operator, many defense dollars could be saved in man power. It would not be necessary for the device to solve the entire manual morse problem but this should be the ultimate goal. If just some of the existing traffic could be handled by such a device, a proportional man power cut could be made.

II. NATURE OF THE PROBLEM

A. SENDING MORSE

Along with the great strides made in communications in the recent years the technique for sending manual morse has also become more precise and automatic. The manual key was the first method for sending morse and was followed by the semiautomatic bug. The electronic keyer followed, whereby the code was punched on paper tape in the form of a series of holes. The tape was then fed through a machine which translated the perforated tape into the morse tones. The latest technique has been the keyboard sender where the paper tape has been eliminated. The operator merely types on a keyboard and the tones are automatically sent.

B. RECEIVING MORSE

There has been much less progress made in the field of receiving manual morse. All techniques up until just recently have dealt with receiving machine sent morse. High speed machine sent morse can be made into an inked recording which is then reduced in speed and passed under a photo cell. The cell then reproduces the tone and an operator transcribes the message. With the advent of magnetic tape the inked recording was replaced but operators were still needed to translate the morse signal.

C. AUTOMATIC TRANSLATING AND TRANSCRIBING OF MANUAL MORSE

This concept of operator unattended translating and transcribing of manual morse is not a new one. In the late 1950's the Massachusetts Institute of Technology used a digital computer to accomplish the difficult task of recognizing morse characters. The software program was called MAUDE for Morse Automatic Decoder. Essentially the Maude program assigned a number to each mark and space. A sliding window algorithm was used to identify the different types (lengths) or marks and spaces. It also featured automatic tracking of hand sent morse in order that changing sending speeds could be handled. With this simulation approach a misinterpretation occurred only once in 10,000 times.[1]

The Department of Defense in 1958 wrote a software program which translates and transcribes hand sent manual morse. This program assigns a binary digit and a number to each mark indicating whether the key is down or up and how long the key is in that position. The length of time the key is in a given position is determined by sampling at periodic intervals and counting the number of samples between changes in key position. The program also has an automatic tracking feature. The need for a digital computer was still apparent. The computer has the ability to

---

[1] Selfridge and Neisser, Pattern Recognition, Scientific American, August, 1960.

receive a message, print it, automatically adjust to slow or rapid changes in sending speed, indicate the points in the text where the transcription technique was so poor that it was necessary to resort to fractionation, and even keep track of the amount of idle time between messages.[2] It should be evident from the two programs cited that the logic necessary to perform the translating and transcribing of manual morse is available.

D. THE BASIC DETECTION PROBLEM

If the senders of morse were able to send accurately and consistently the problem of automatic translation and transcribing would not exist. If the various mark and space types were to remain uniform the detection problem would be greatly simplified. Figure 1 illustrates the distribution of morse elements produced by a typical operator.[3] The abscissa gives the range of mark or space lengths and the ordinate represents the number of times they occurred. The values above the center line are for marks and the values below the center line represent spaces. Reading the graph from left to right the first cluster represents dots; the second represents dashes. Below the center line the first cluster represents element

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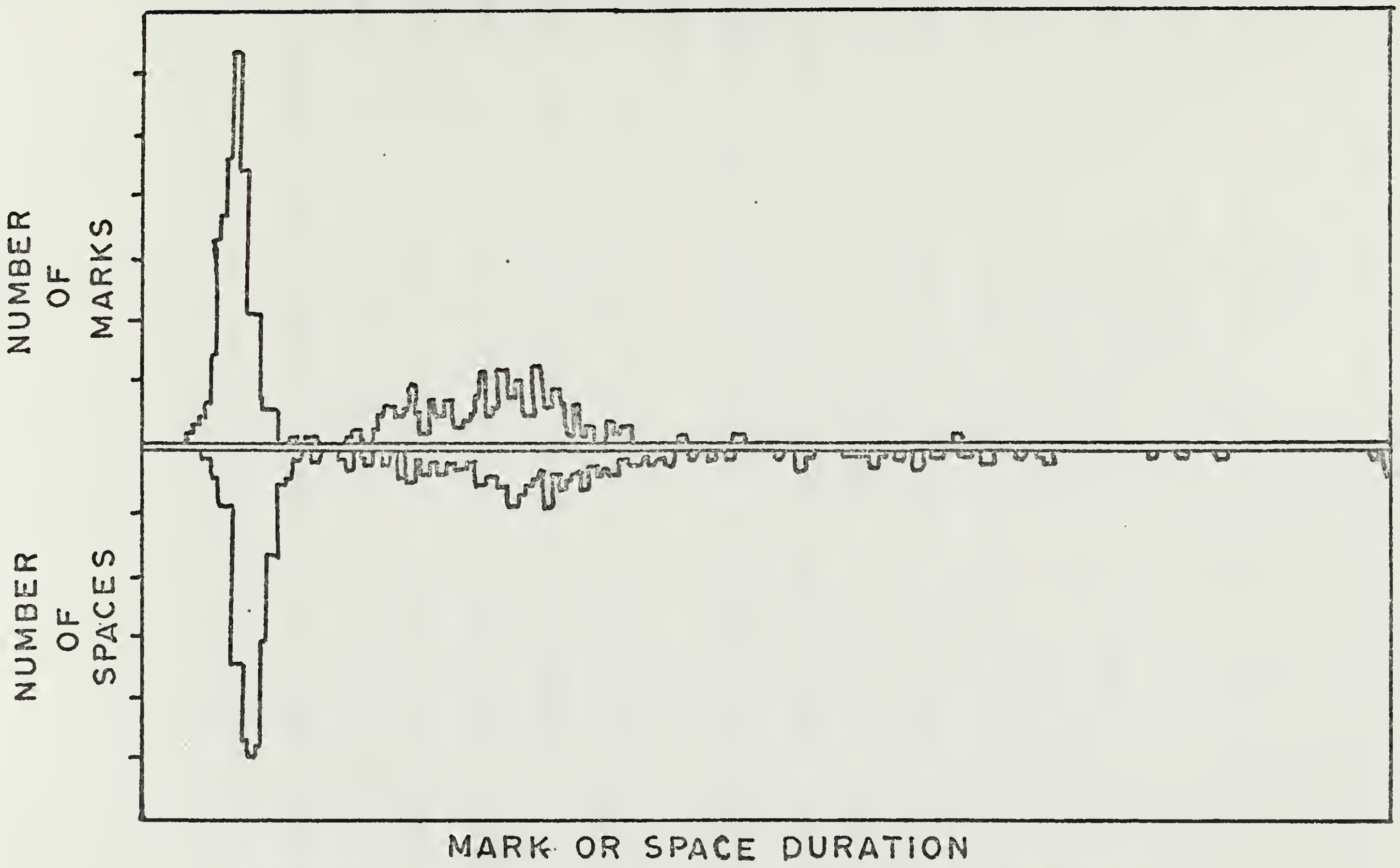
[2] Blair, Charles R., On Computer Transcription of Manual Morse, Journal of the Association for Computing Machinery, Vol. 6, No. 3, July 1959, p 440.

[3] Ibid., p 434.



MARK SPACE DISTRIBUTION

FIG-1

spaces; the second is character spaces. The rest of the distribution spread out to the right represents word spaces. The inconsistency of the length of dots, dashes, and the three types of spaces is seen as distributions. In the ideal case a dot would be of one unit length, a dash 3 unit lengths. An element space would be one unit length, a character space 3 unit lengths and a word space would be 7 unit lengths. As can be seen from Figure 1 the mark and space durations form distributions about each one of these. A convenient way of referring to the amount an operator deviates from the ideal is the concept of weighting. The weight of some particular code is defined as dot length divided by dot length plus element space length. Perfect code has a weight of 50%. Weights of greater than and less than 50% cause the distributions to occur.

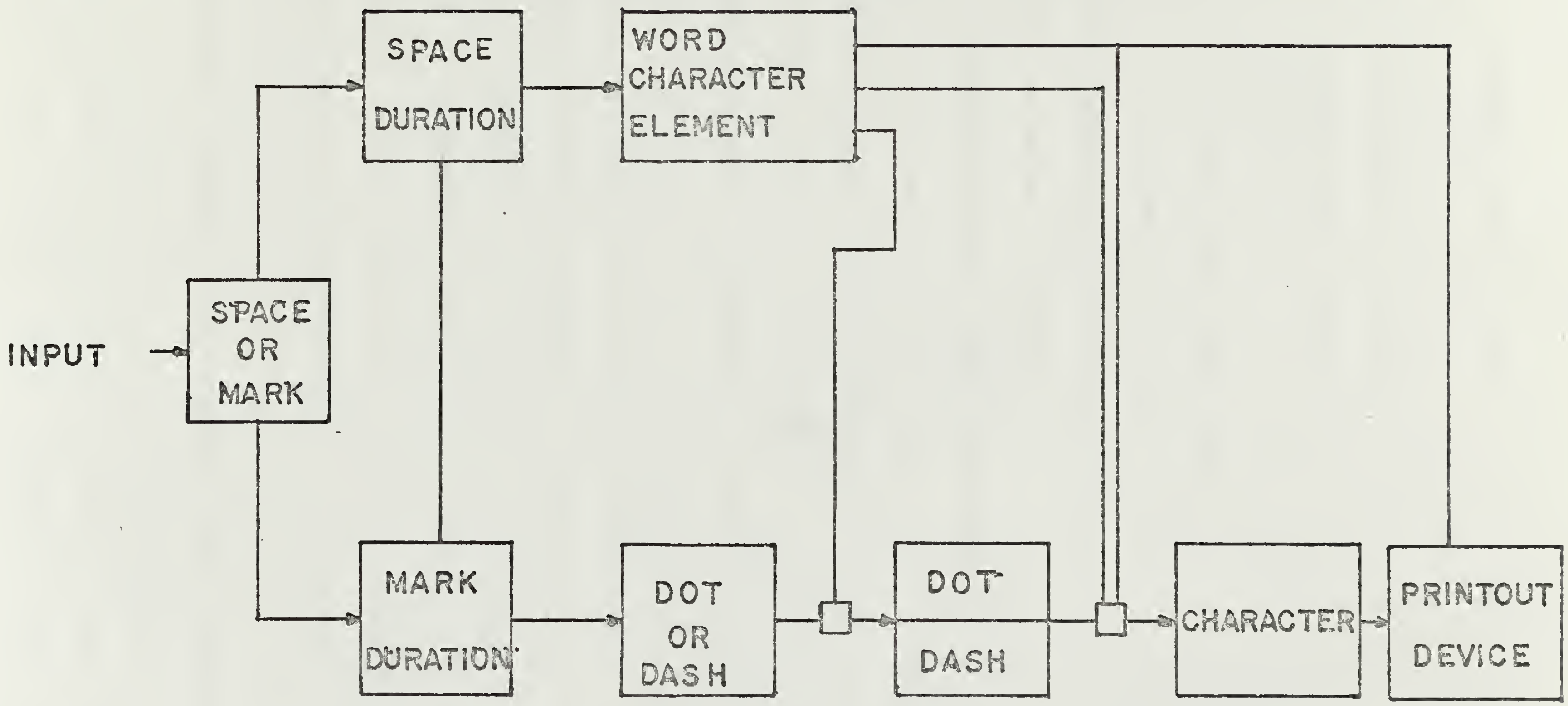
Another problem in the detection of morse is the variance in code speed (words per minute). An operator may vary his speed when sending different types of messages or he might start out slow and increase his speed when he establishes some rhythm. Any device used to translate and transcribe manual morse must have a provision for coping with different weight code and differing speeds.

III. THEORY OF OPERATION

The basic design of this device to automatically translate and transcribe manual morse was that of VMG Electronics of Phoenix, Arizona. Modifications were made and the system tested. The overall theory of operation will be given referring to Figure 1a. A more detailed explanation will follow.

There are essentially two paths which the marks and spaces can take. A decision is made as to whether a space or a mark is present. If a mark is detected it proceeds in the lower portion of Figure 1a. After the duration of the mark has been detected a decision is made, based on the duration, whether a dot or a dash has been received. The dot or dash is then transferred to its appropriate storage until a full character is assembled. When a character has been completed it is placed in a character storage where it is held until it can be decoded and printed out.

If a space is detected it will move along the upper portion of Figure 1a. The duration of a space is measured in the same manner as a mark but is done by a separate piece of circuitry. The beginning of a space is signaled by the end of a mark and similarly the beginning of a mark is signaled by the end of a space. A decision is made, based on the duration of the space, whether an element,



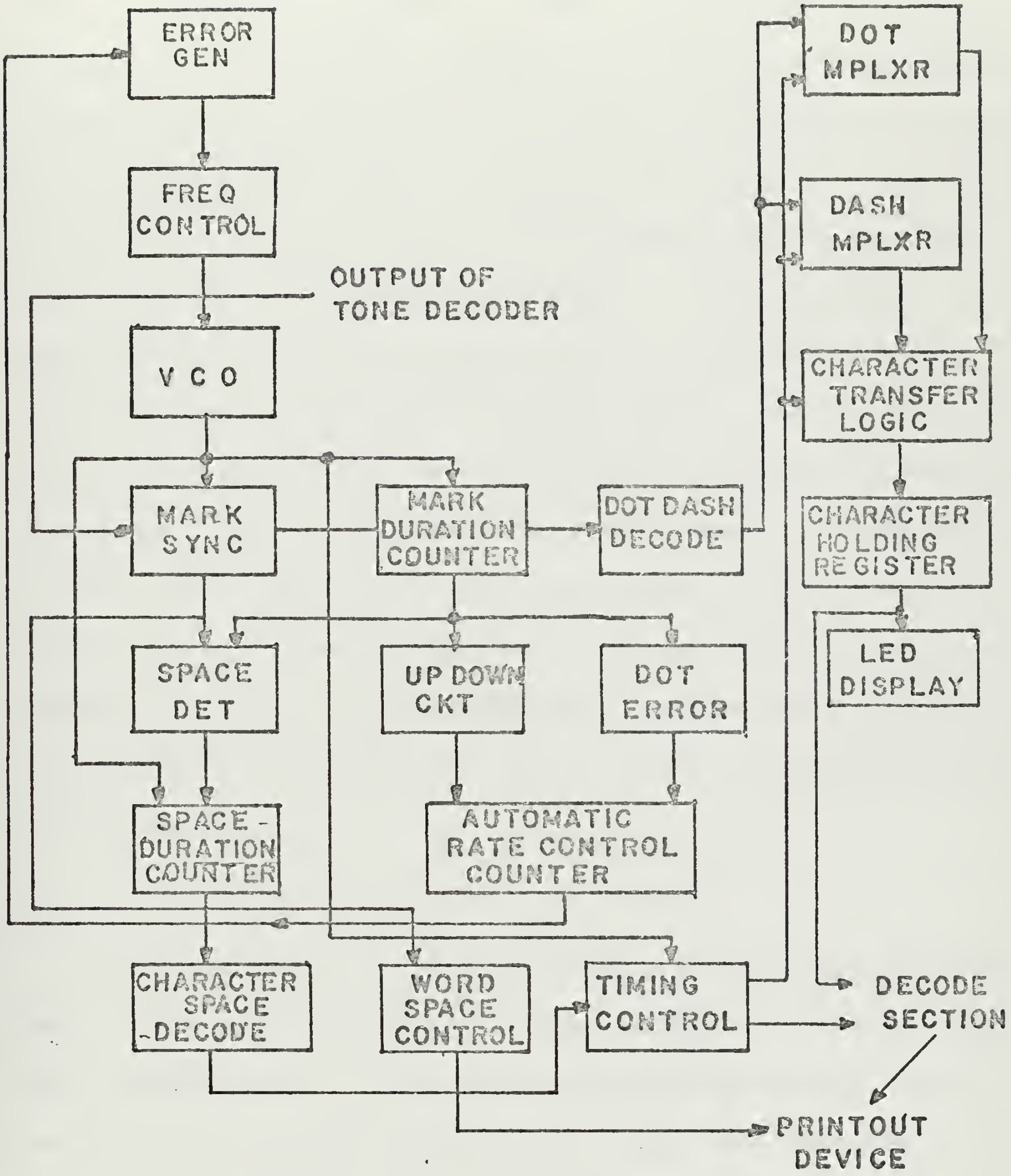
BASIC BLOCK DIAGRAM

FIG - 1a

character or word space has been detected. The detection of an element space transfers the dots and dashes into their respective storage. The detection of a character space controls the transfer of the completed character from the dot dash storage into the character storage. The recognition of a word space performs the same action as a character space plus indicating to the print out device to increment one space without printing a character. A more detailed block diagram with all the individual blocks is shown in Figure 2.

The audio output from the receiver is brought into the tone decoder where the cw signal is transformed into dc levels which follow the original keying characteristics. The output of the tone decoder is fed into the mark synchronizer where the mark is synchronized with the internal clock. The mark starts and stops the mark duration counter which registers the duration of the mark. Essentially this counter performs a digital integration of the mark. At the end of the mark the dot dash decode decides whether the mark is a dot or a dash. The decision is then stored in the dot or dash multiplexer and the counter is reset. Each dot or dash is shifted into its respective register until the entire character has been received. Then all the character elements are available for translation.

At the end of a mark the space detector starts the space duration counter. The counter stops upon the receipt of the next mark or until it becomes full. A count of one



BLOCK
DIAGRAM

FIG-2

to twelve in the space duration counter is detected as a dot. A count of thirteen or over is detected as a dash. A space count of one to twelve is detected as an element space, thirteen to thirty as a character space and thirty or over as a word space. If an element space is detected the mark duration counter again counts clock pulses and the space duration counter is reset. If a character space is detected the timing control generates a pulse which transfers the elements being held in the multiplexers into the character holding register via the character transfer logic. The multiplexers are then reset for the receipt of the next character. If a word space is detected the space duration counter is reset as with the receipt of a character space. From this point the character holding register supplies the LED display and the decoding portion of the device.

A. TONE DECODER CIRCUIT

The tone decoder circuit is one of the modifications that was mentioned earlier. This circuit is essentially the Signetics 567 Tone Decoder integrated circuit with its accompanying external components. The tone decoder receives the audio output from the receiver and transforms it into +9 volts signal absent and 0 volts signal present. It's a simple matter to invert this output to interface with the logic circuitry. The effectiveness of the tone decoder will be discussed later. The frequency that the

decoder responds to is controlled by the variable 25K resistor shown in Figure 3.

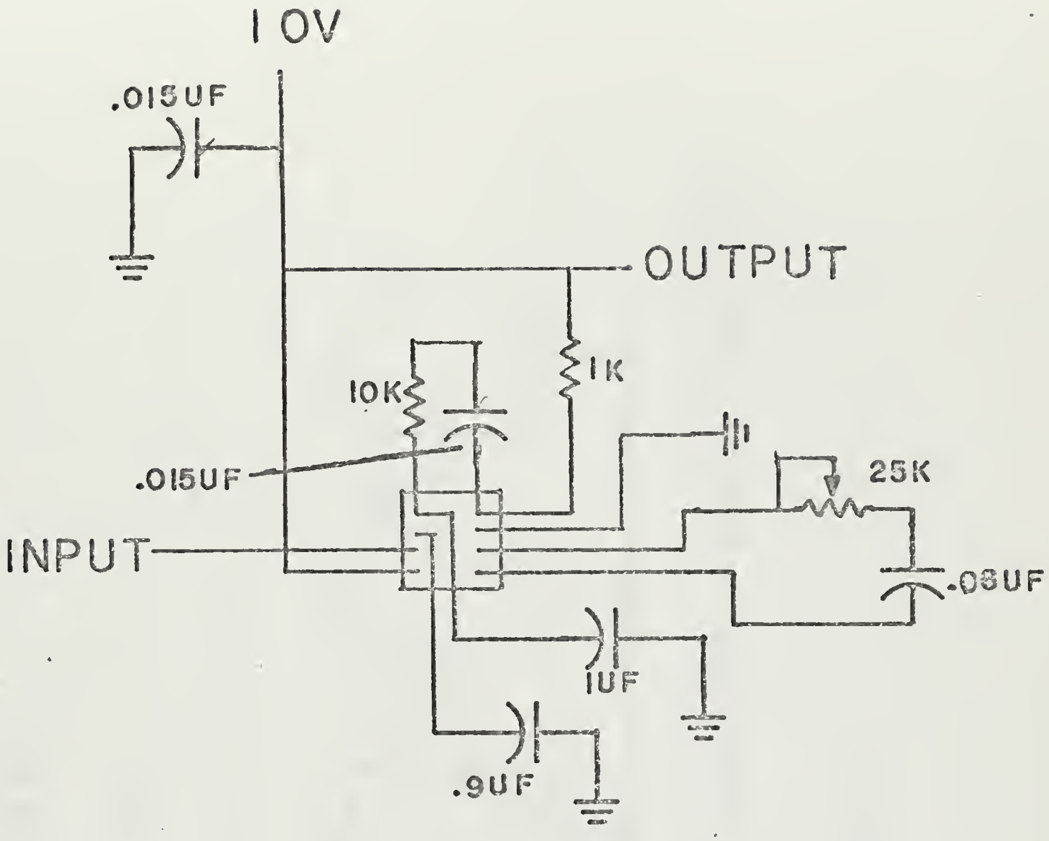
B. MARK SYNCHRONIZER AND MARK DURATION COUNTER

The mark synchronizer synchronizes the mark with the internal clock. This is necessary to assure the correct timing relationships within the rest of the circuit. It is made up of one flipflop with the mark connected to the J input and mark inverse connected to the K input. When the mark occurs at the next clock pulse a high occurs at the one output of the flipflop which is the synchronized mark.

The mark duration counter is shown in Figure 4. It is a 4 bit binary counter. When the sync mark goes positive the counter counts up. When and if the counter reaches a count of thirteen the counter freezes at thirteen. The counter is reset when the decision is made whether a dot or a dash has been received. As stated previously a count of one to twelve is a dot and thirteen and over is a dash. Since the count indicates either a dot or a dash one is the inverse of the other.

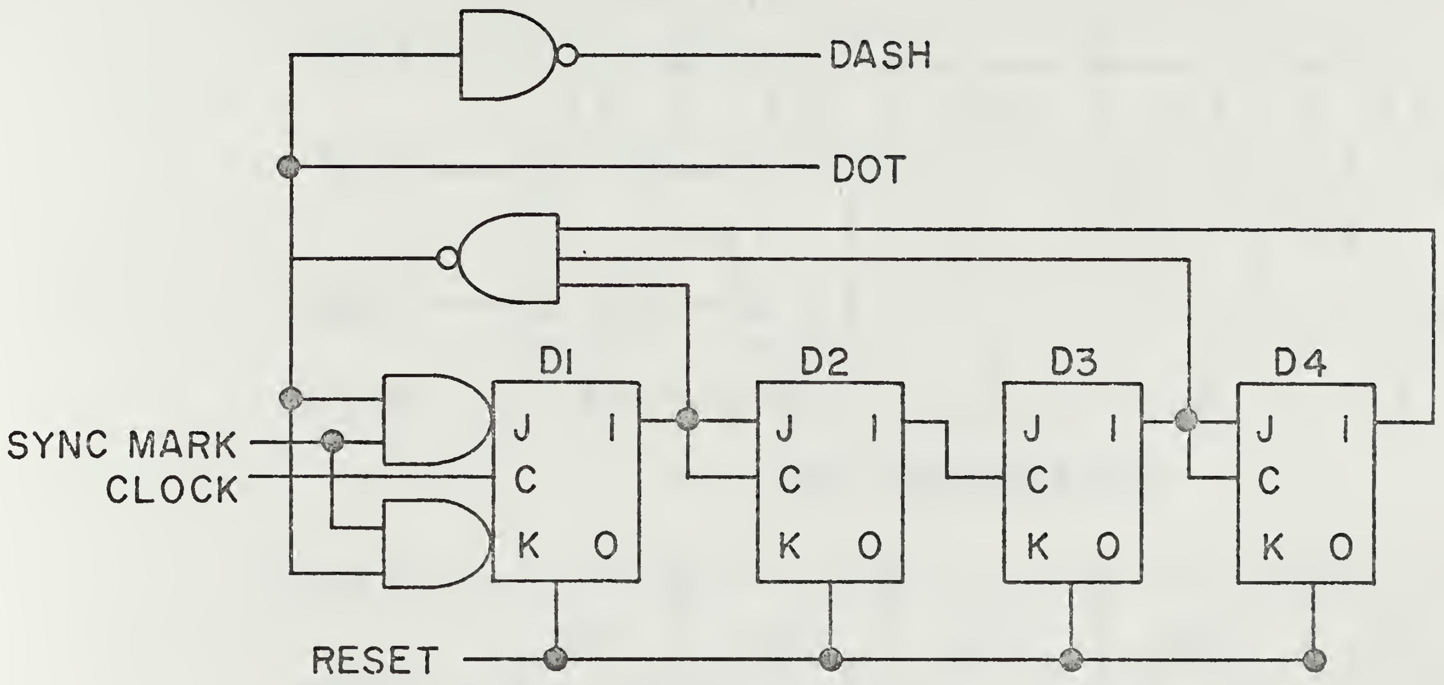
C. DOT/DASH MULTIPLEXERS

When a dot or a dash decision has been made this decision must be stored somewhere until all the elements are collected to form a character. This is the function of the dot/dash multiplexers. Each multiplexer is a 5 bit shift register as shown in Figure 5. Up to five



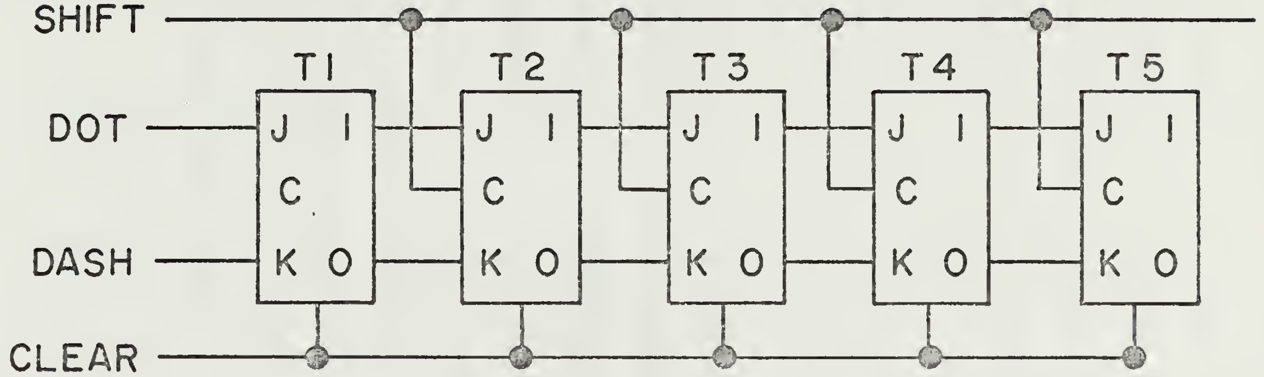
TONE DECODER
CIRCUIT

FIG-3

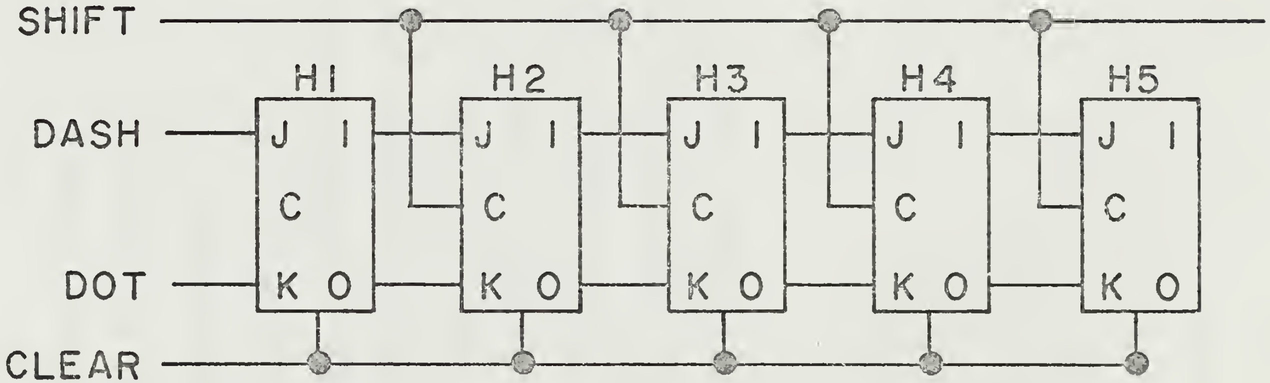


MARK DURATION COUNTER AND DOT / DASH DECODER.

FIG- 4



DOT MULTIPLEXER



DASH MULTIPLEXER

FIG-5

elements can be shifted into each one. If a character should consist of more than five the first element which now resides in T5 or H5 is shifted out. The sixth element is shifted into T1 or H1. The special symbols which are truncated in this manner are still uniquely determined. Notice here that there are three states to be represented. There is either a dot or a dash or neither. If both T1 and H1 for example contain a zero a null state resides in stage one. If there is a one in H1 and a zero in T1 a dash is present in stage one. If a one in T1 and a zero in H1 then a dot is stored in stage one.

D. CHARACTER TRANSFER LOGIC AND HOLDING REGISTER

There are five stages to the transfer logic and holding register corresponding to the 5 stages in the dot dash multiplexers. The first stage is shown in Figure 6. The other four stages are identical to this one. Each stage of the holding register is a latch which holds the element from its particular stage of the multiplexers. When a character space is detected a pulse is generated which sends the multiplexer elements into the holding register. The multiplexers are then cleared to be ready to accept a new character. The holding register retains the character until it can be translated and printed out. If T1 is positive at the time the character transfer pulse is present the set dot 1 output goes negative latching in a dot 1 state in the holding register. The dot 1 state goes positive while the dash 1 and null 1 state goes negative.

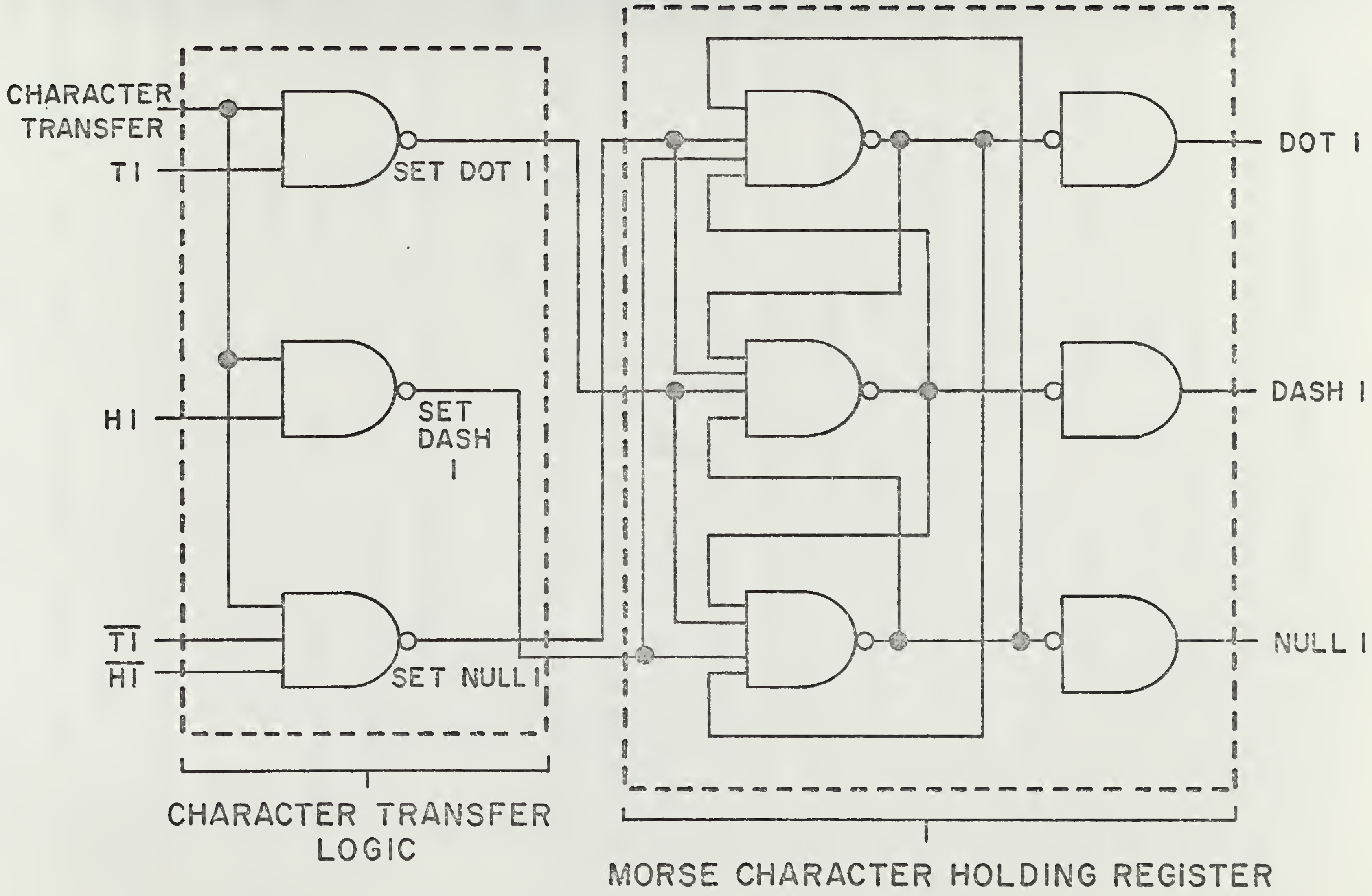

CHARACTER TRANSFER
T1
H1
$\overline{T1}$
$\overline{H1}$
SET DOT 1
SET DASH 1
SET NULL 1
DOT 1
DASH 1
NULL 1
CHARACTER TRANSFER LOGIC
MORSE CHARACTER HOLDING REGISTER

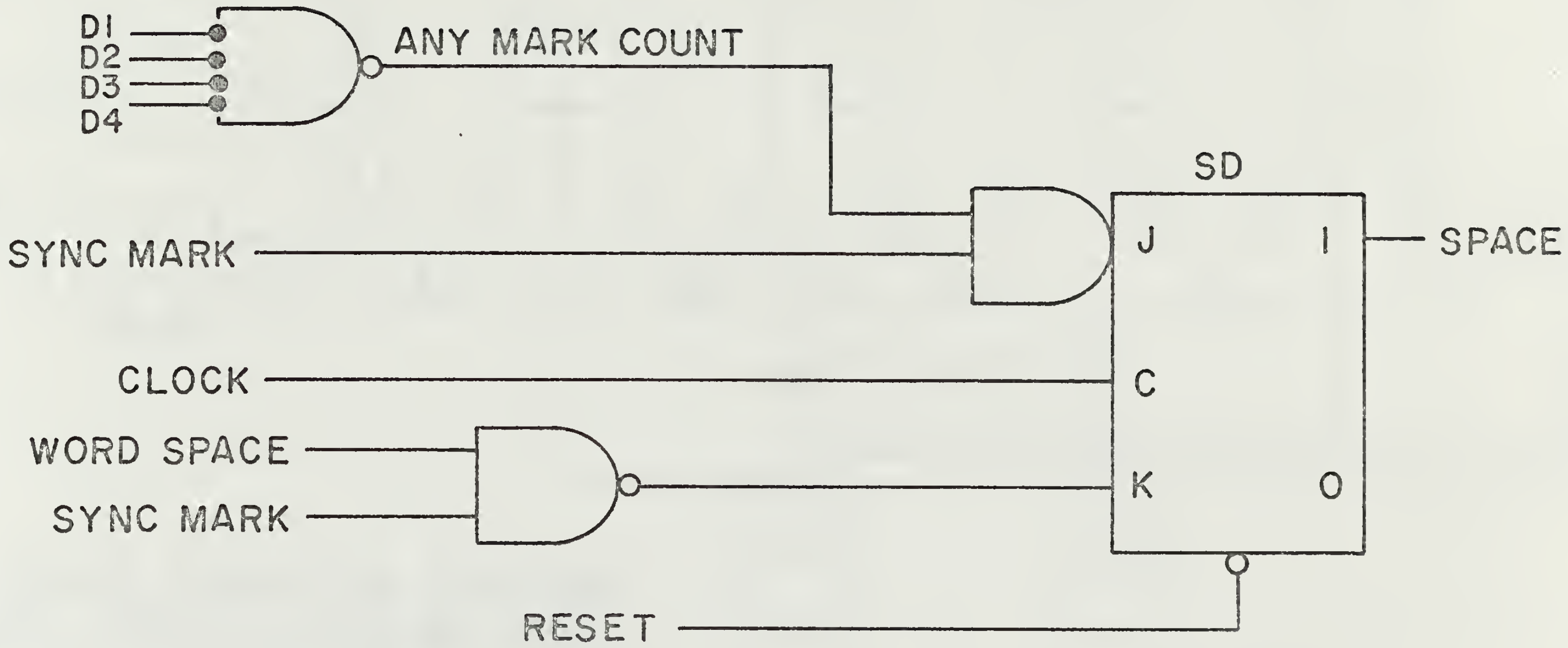
FIG-6

E. SPACE DETECTOR

The space detector, shown in Figure 7, is a single flip-flop which is set at the beginning of each interval in-between marks and reset at the beginning of the next mark if it occurs before a word space is detected. If not, it is reset upon the receipt of a word space. The flip-flop is initially in the reset condition. If the mark duration counter has any count above zero the output of the gate labeled "any mark count" is positive. At the end of the mark signal sync mark goes positive enabling the set side of the flip-flop. On the next clock pulse the flip-flop is set. The flip-flop will remain in the set condition signifying a space until the output of the gate connected to the K side of the flip-flop goes positive. This occurs either when a sync mark or a word space occurs. The flip-flop is reset on the next clock pulse and hence the end of the space.

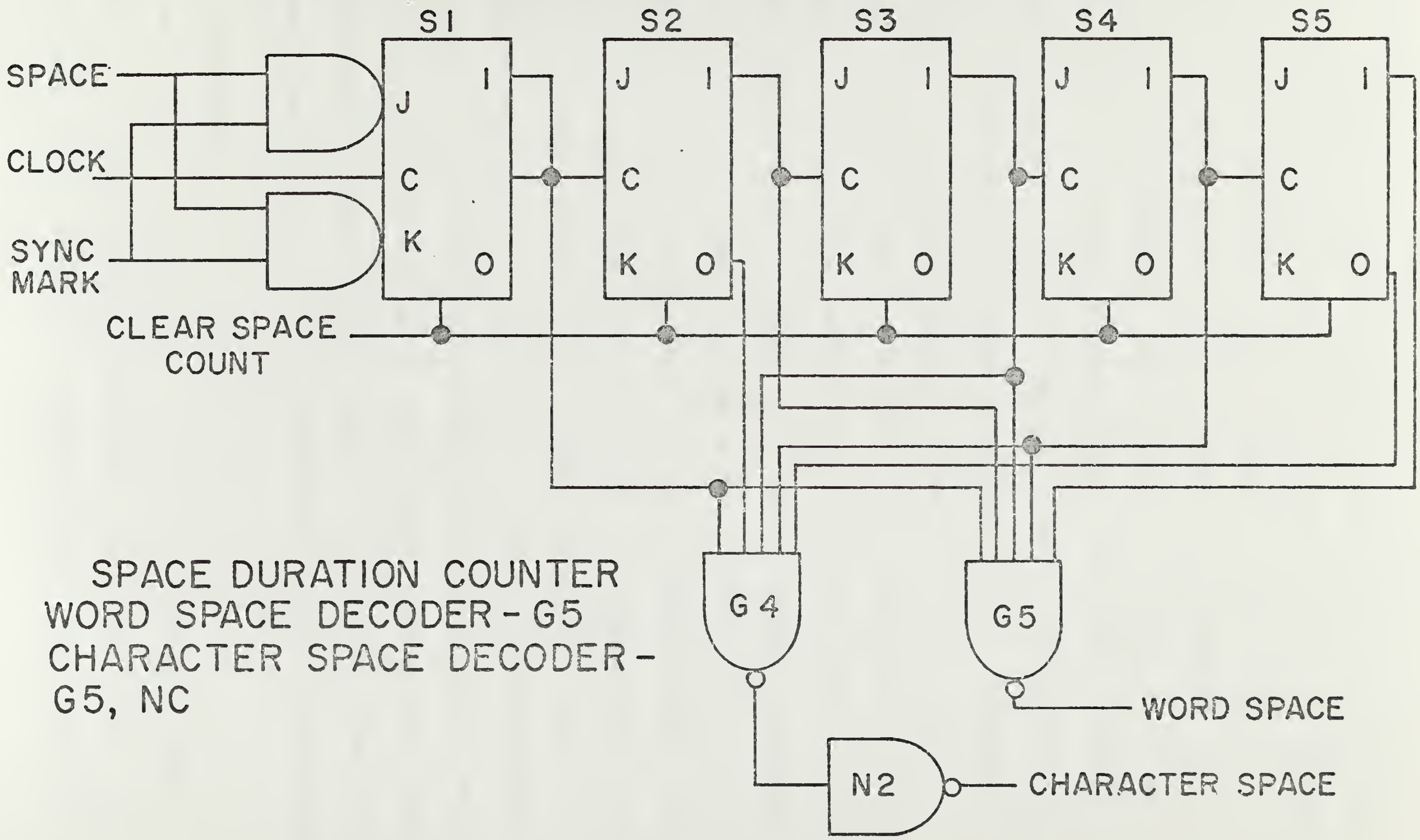
F. SPACE DURATION COUNTER AND SPACE DECODER

The space duration counter is a five bit binary counter. It counts during the time the space detector is in the set condition. The counter is reset upon the receipt of a mark or a word space. As shown in Figure 8 the character and word space decoders are gates G4 and G5 respectively. The indication of a character space is sent to the timing control where a character transfer pulse is formed. The indication of a word space also generates a character transfer pulse.



SPACE DETECTOR

FIG- 7



SPACE DURATION COUNTER
WORD SPACE DECODER - G5
CHARACTER SPACE DECODER - G5, NC

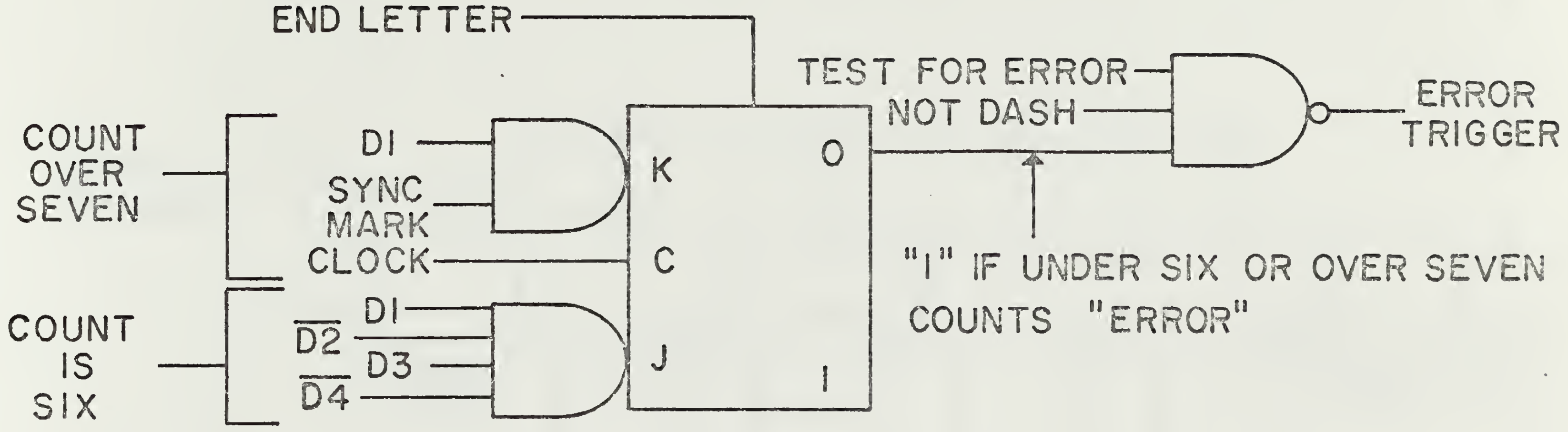
FIG-8

G. AUTOMATIC RATE CONTROL

In a previous paragraph the two problems in detecting manual morse were the difference in weights and the changing speed of the sender. The automatic rate control attempts to solve the latter of these two problems. Essentially the automatic rate control is composed of an up/down four bit binary counter and a dot error circuit as shown in Figures 9 and 10. The principle of operation is based on ideal dot length of six clock pulses. Earlier it was mentioned a dot could range between one and twelve counts. As can be seen in Figure 9 the dot error circuit produces a pulse if the count is under six or above seven in the mark duration counter. The pulse is only produced when a dot is detected. If the count is less than six the counter will count up one and if on the next dot the count is still less than six it will count up one more and so on until the ideal count of six is again reached. The same procedure takes place if the count is above seven except the counter will count down until the ideal count is reached. The outputs of the automatic rate control become the inputs to the master clock. In this way the necessary feed-back is accomplished in order to cope with the varying sending speed.

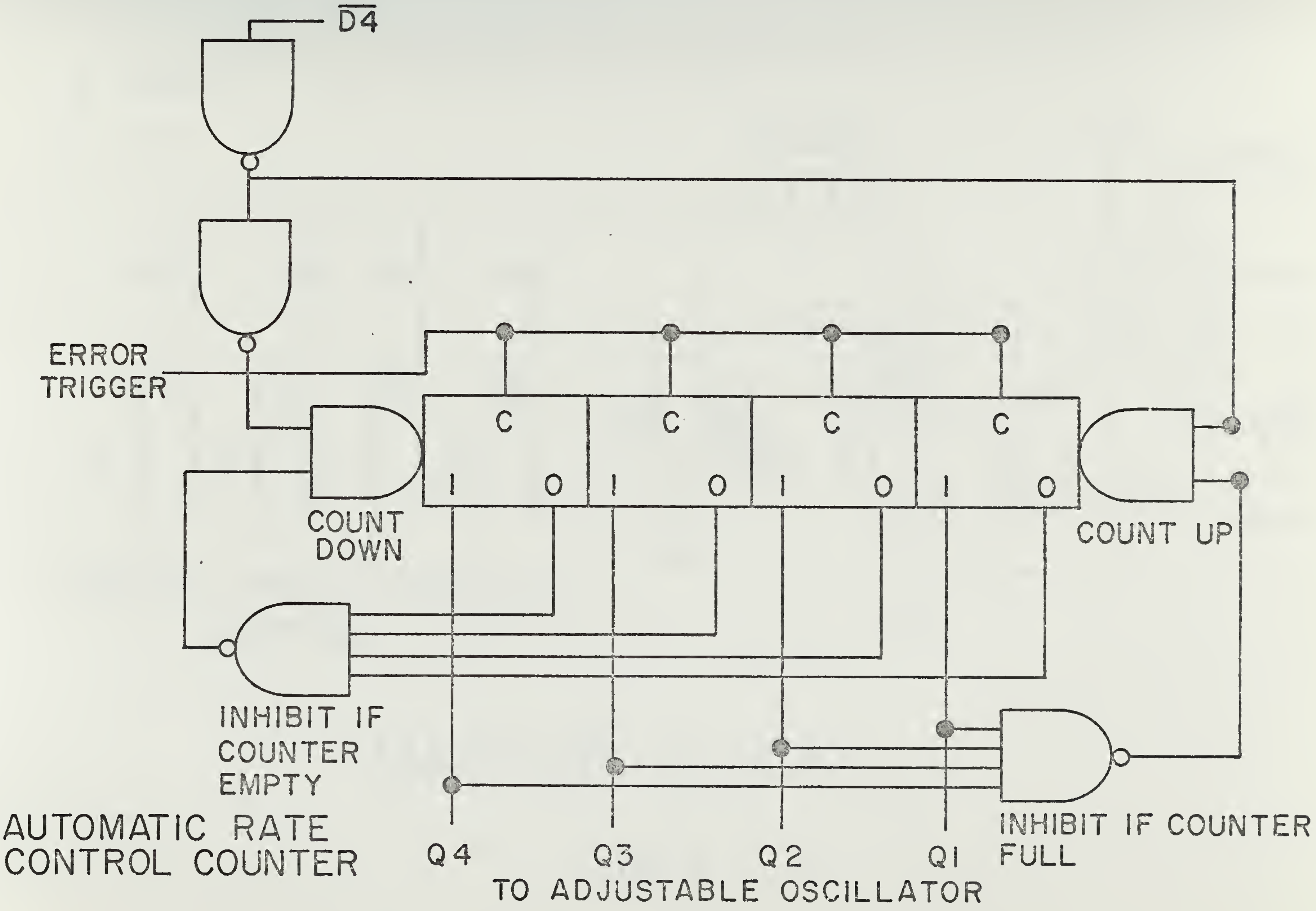
H. MASTER CLOCK

The master clock circuit (Figure 11) contains four transistor switches whose bases are connected to the four flip-flops of the automatic rate control. The collectors



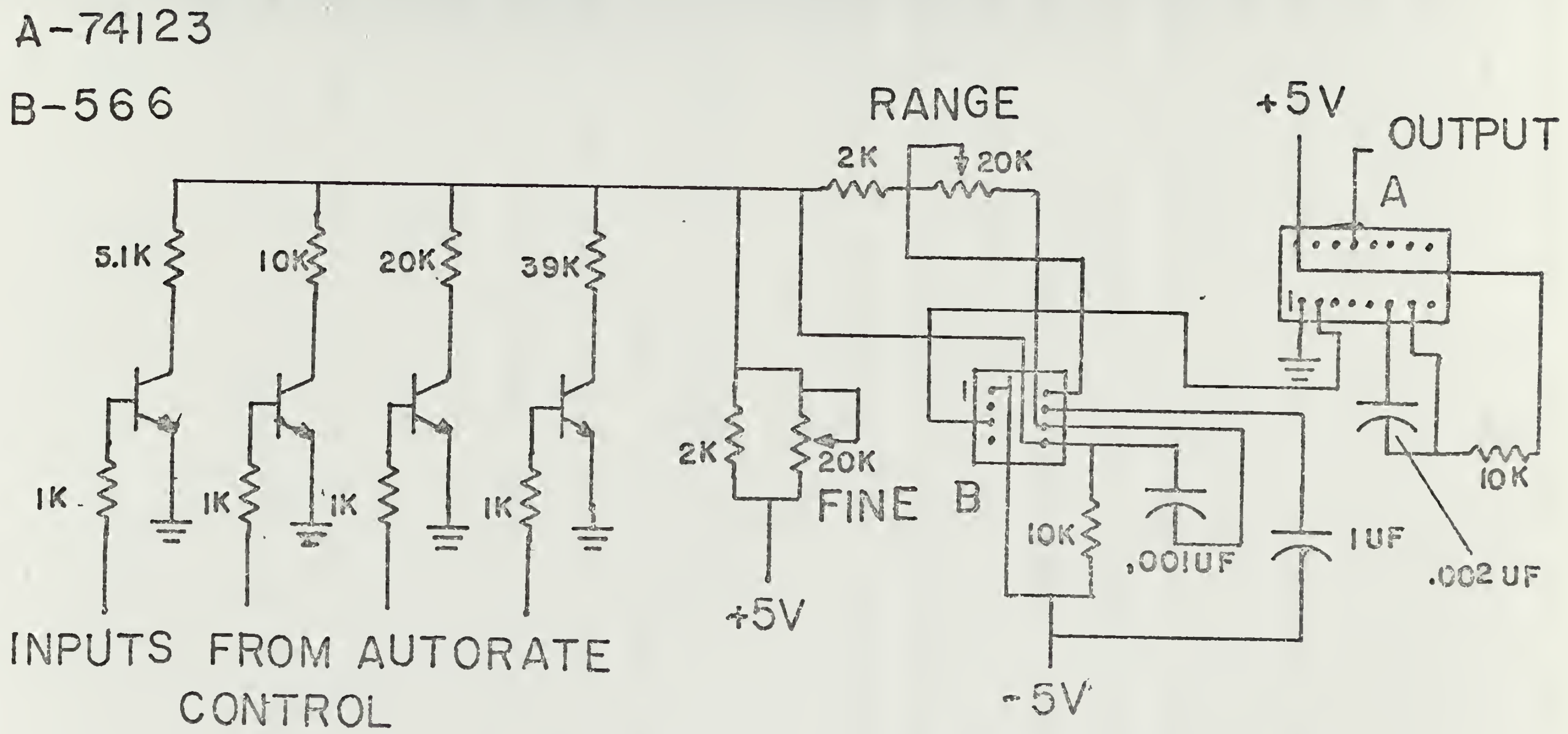
DOT ERROR TRIGGER

FIG-9



AUTOMATIC RATE CONTROL COUNTER

FIG-10



MASTER CLOCK

FIG-11

of these transistors have resistors which are graduated in a binary fashion. The master clock also contains a 566 function generator which is a voltage controlled oscillator having a square wave output. The frequency of the 566 is voltage controlled over a ten to one frequency range. The voltage control is determined by the variable resistor marked FINE and the four resistors. The basic frequency of the 566 is determined by the variable resistor marked RANGE. The monostable multivibrator (74123) is used to create a one microsecond pulse from the square wave output of the 566. By turning on and off the transistors different resistors are switched into the circuit thereby controlling the voltage to the 566.

I. TRANSLATOR AND PRINTOUT DEVICE

The translator used in the original design is a diode matrix which compares the desired morse character with that of the corresponding letter on a print wheel. The print out device used is a paper strip printer. The translator and associated circuitry for the print out device was not constructed because it was felt a more efficient method could be used. This method will be discussed in a later section.

IV. TEST AND EVALUATION

A. TONE DECODER

As stated earlier the tone decoder was used to transform the cw signal into dc logic levels. The tone decoder has a bandwidth lock-up time restriction. As the bandwidth is reduced the number of cycles received before the output changes is increased. The tone decoder determines the signal to noise ratio in which the entire device will operate dictating a narrow bandwidth. The device must also operate at relatively high code speeds necessitating a minimum number of cycles before an output. A test was set up to mix noise and signal and determine what the minimum signal to noise ratio could be with a minimum lock up time and maximum bandwidth. The results can be seen in Figures 12 and 13. The top trace in Figure 12 represents the 1000 HZ tone as recorded on a cassett tape. The noise in this case is just the tape noise. The lower is the output of the tone decoder which is the zero level. The positive level was left out in order to give an actual picture of dots and dashes. In Figure 13, however, white noise from 5 HZ to 1 KHZ was mixed with the signal until the tone decoder began to register false outputs. At this time the amount of noise was reduced until these false outputs disappeared. As seen in Figure 13 the signal to noise ratio

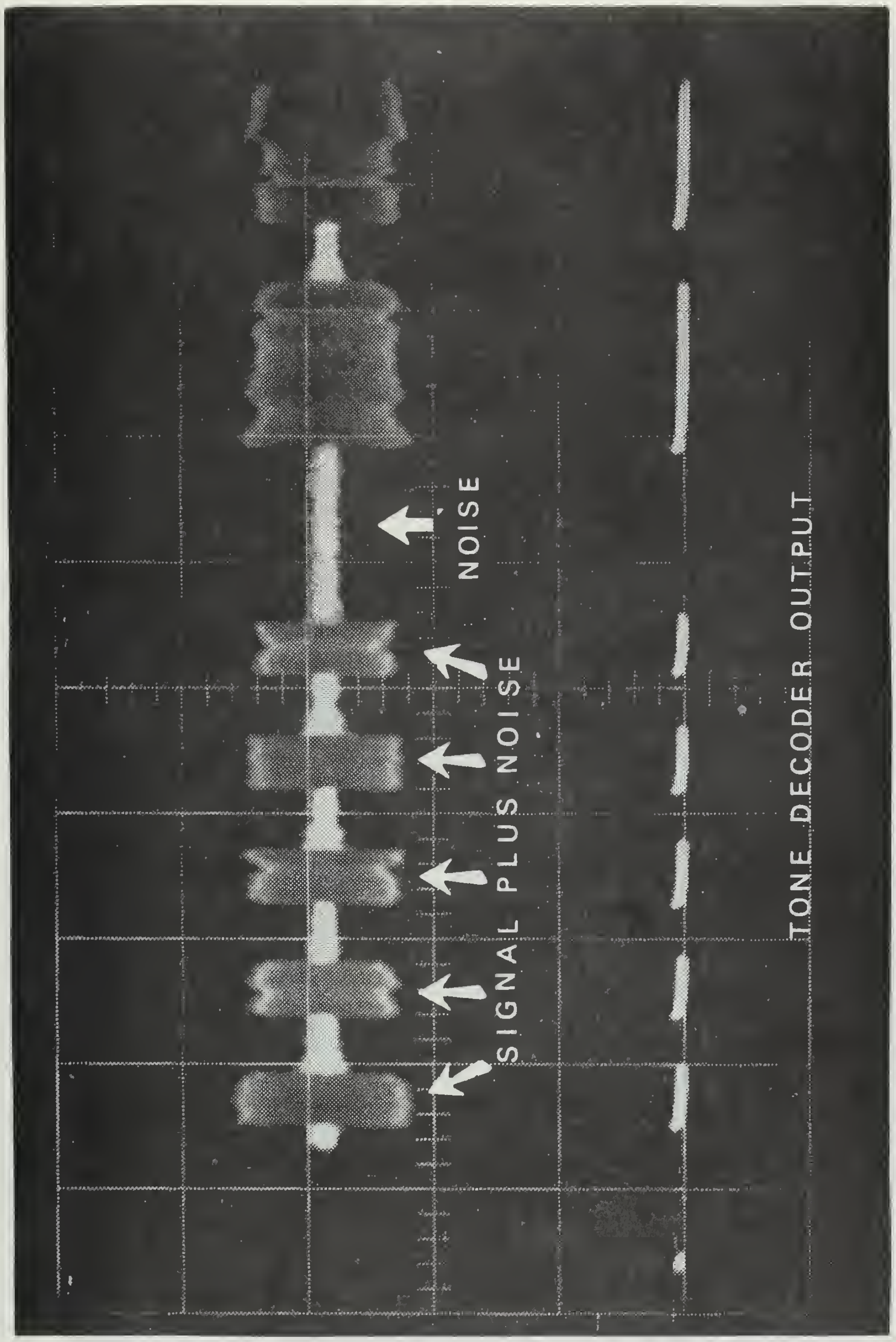


FIG-12

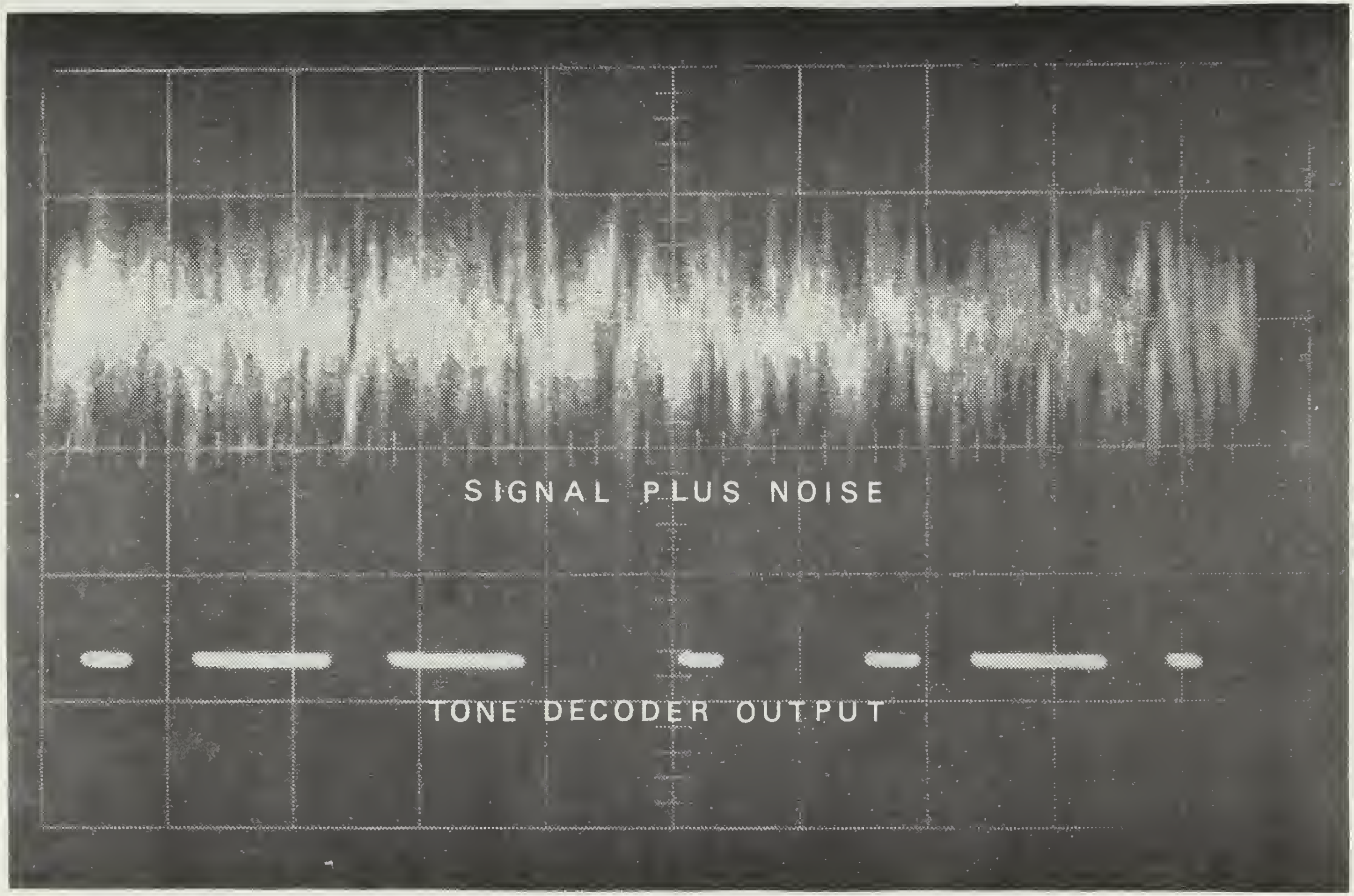


FIG-13

is quite small. A picture in this case was used to describe signal to noise ratio since there are various ways in which it can be defined. The decoder does have a limitation of a minimum detectable signal of approximately 200 millivolts at the input of the tone decoder.

B. ACTUAL CODE TESTS

The LED display was used to determine whether the morse characters were detected correctly. An insufficient amount of time prohibited full development and construction of the decoder and interface with the print-out device. The display consists of five groups of three LEDs each. One group represents one element of a five element or less character. A dot is displayed if the center LED is on in a group. A dash is represented when all three LEDs are on and neither a dot or a dash is given when none of the LEDs are on. The character is read from left to right. As the dot dash tones were heard the correct response was noted on the LED display. Aural to visual correlation ability limited test code speeds to about nineteen words per minute.

The first test was made with a signal of the quality shown in Figure 12 along with a constant code speed of twelve and nineteen words per minute. The tape was run for approximately six minutes for each code speed and no errors were detected.

The next logical step was to test its ability to track varying code speeds. A hand keyed test tape was made with

code varying in speed from ten to twenty words per minute. It was found if the device was calibrated on fifteen wpm it could not track to the extreme ranges. Consequently the values of resistances in the master clock switches were changed to allow a larger variation in control voltage. After this change was made the same test tape was played for fifteen minutes without error. During the test the master clock was monitored and could be seen to change in increments as the up/down counter in the automatic rate control adjusted to an ideal dot count of six. When the device is calibrated the up/down counter is set to binary eight and the clock is adjusted until the dot indicator light begins to flash. Then the switch is put in the run position to begin automatic tracking. It was found when the up/down counter was set to binary eight, the clock was at the mid point of its range; this was probably due to resistance tolerances. In order for the clock to be at its mid range when in the calibrate position the counter had to be set to binary five. The system would then track from thirteen wpm to twenty-seven wpm when calibrated at twenty wpm. Most manual morse is sent in this range. It should be noted that the varying speed test tape had code speed changes which were quite rapid, approximately three to five wpm in four characters.

Another test was conducted to find out how the device reacted to abrupt changes in code speed. The machine was calibrated at nineteen wpm; then it was switched into the

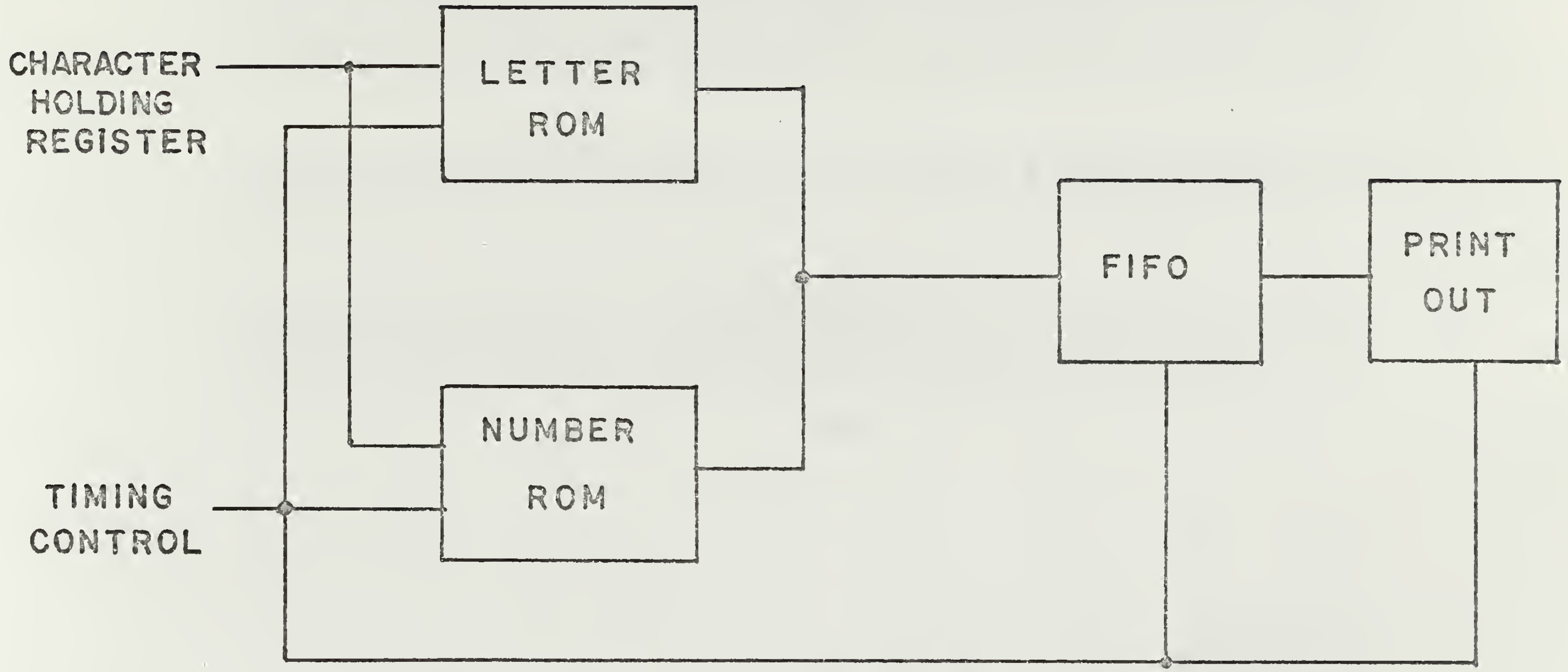
run position and the code speed changed to twelve wpm. This was also done changing from twelve to nineteen wpm. The machine missed on the average of about four characters. This was expected due to the fact that the automatic rate control only compensates one step at a time and only on dots. The "catch up time" is dependent on how many dots are received after the change in speed is made and how large the change is. There might be two ways to speed up the "catch up time". The first by incrementing on dash errors as well as dot error. The second by detecting not only whether the received dot or dash is longer or shorter and by what amount and correcting the counter accordingly. It is felt that at most one character would be missed when changing speeds instantaneously.

These tests would indicate that given a proper signal level and signal to noise ratio that this device could perform a considerable amount of morse translating done by operators in the field today.

V. AREAS FOR FURTHER DEVELOPMENT

A. DECODING AND PRINT OUT CIRCUITRY

As mentioned in a previous section the basic design used a diode matrix composed of approximately seven hundred diodes as the decoder. The print out device was a paper strip printer. With the advent of integrated circuits the diode matrix could be replaced with a Read Only Memory. The print out device could be a teletype terminal or alpha-numeric display. The block diagram of such a system is shown in Figure 14. The ROMs could be 8223 field programmable ROMs. These ROMs have a five bit address with thirty-two words of 8 bits. One would be needed to decode the letters and the other to decode the numbers and special symbols. There are ten outputs from the character holding register so a scheme must be devised to reduce these ten bits into five bits for the ROMs. The coding has been worked out and is shown in Table I. Since the first two bits are either 00 for letters and 01 or 10 for numbers they can indicate which ROM is to be used. The next six bits are reduced to four by some combinational logic whose min terms are shown on Table I. The last two bits are either 10 or 01 so the last bit can be dropped for letters. For numbers use the odd number bits.



DECODE AND PRINTOUT SECTION

FIG - 14

TABLE I. ROM Coding

I	II	III	IV
	xyzuvw	abcd	
A	0000000110	00011	1000001
B	0010010101	01010	0100001
C	0010011001	01100	1100001
D	0000100101	10010	0010001
E	0000000001	00000	1010001
F	0001011001	01110	0110001
G	0000101001	10100	1110001
H	0001010101	01000	0001001
I	0000000101	00010	1001001
J	0001101010	10111	0101001
K	0000100110	10011	1101001
L	0001100101	10000	0011001
M	0000001010	00101	1011001
N	0000001001	00100	0111001
O	0000101010	10101	1111001
P	0001101001	10110	0000101
Q	0010100110	11111	1000101
R	0000011001	11100	0100101
S	0000010101	11010	1100101
T	0000000010	00001	0010101
U	0000010110	11011	1010101
V	0001010110	01001	0110101
W	0000011010	11101	1110101
X	0010010110	01011	1111101
Y	0010011010	01101	1001101
Z	0010100101	11110	0101101
0	1010101010	11111	0000110
1	0110101010	01111	0100110
2	0101101010	00111	0100110
3	0101011010	00011	1100110
4	0101010110	00001	0010110
5	0101010101	00000	1010110
6	1001010101	10000	0110110
7	1010010101	11000	1110110
8	1010100101	11100	0001110
9	1010101001	11110	1001110

I - Letters and numbers
II - Ten bits from the morse character holding register
III - Five bit address
IV - Eight bit ASCII

$$a = u\bar{x} + \bar{x}\bar{u}w + x\bar{v}$$

$$b = u\bar{x} + x$$

$$c = u\bar{x} + y\bar{z}$$

$$d = u\bar{x} + \bar{u}\bar{v}\bar{x}z + \bar{u}vy\bar{z} + \\ + ux\bar{y}$$

Since the rate at which a teletype prints out information is constant and the rate at which morse characters are received is erratic a buffer must be inserted between the two devices. Again integrated circuitry solves the problem.

There is currently available a MOS device called a First In First Out Buffer (FIFO). The device is four bits long and can hold up to sixty-four words. Two of these devices would be needed in parallel to handle the eight bit ASCII. The FIFO would be located as shown in Figure 14. The output of the FIFO could then be made available to a teletype terminal or alphanumeric display.

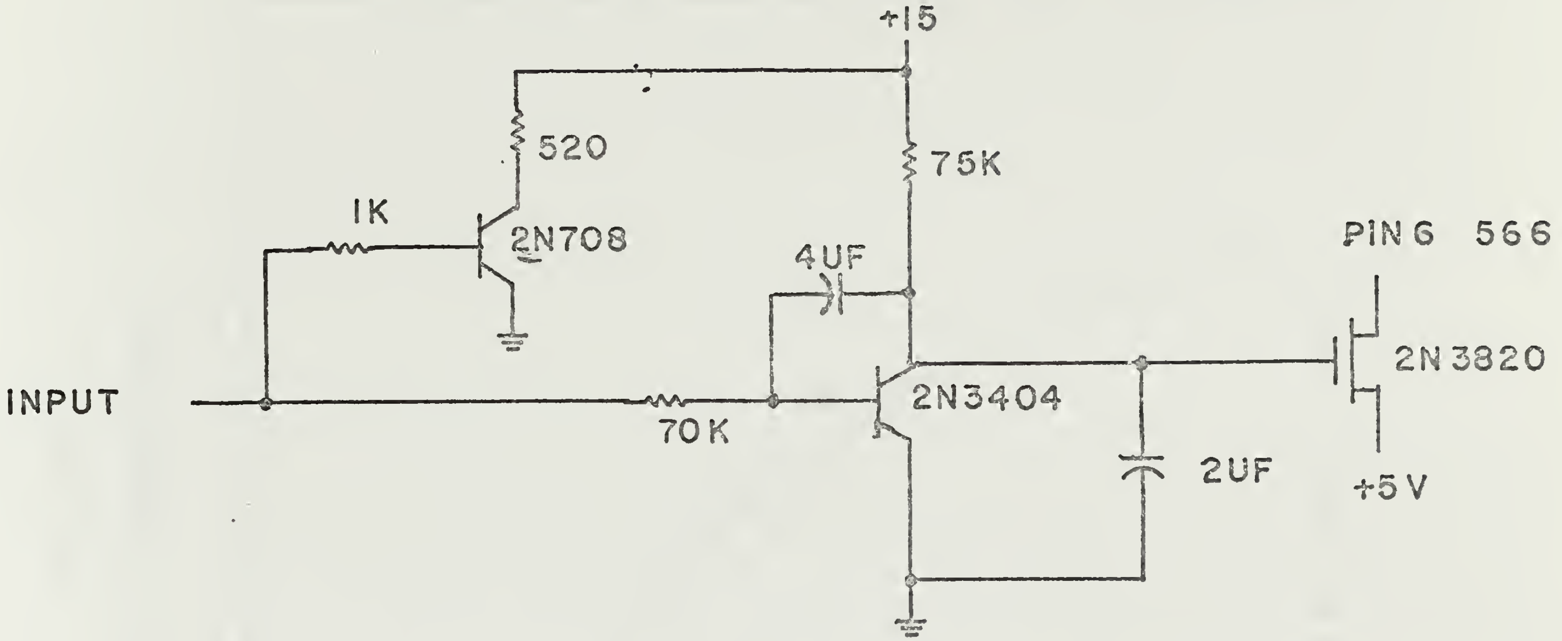
B. AUTOMATIC RECALIBRATION

As mentioned previously the machine must be calibrated before it is switched into its automatic track mode. If the code speed should vary out of its tracking range the machine must be recalibrated by the operator. There are indicator lights which tell the operator that a recalibration is necessary. It might be advantageous to eliminate this operator function and possibly the operator.

Essentially a recalibration consists of moving the range of the master clock into an area where it can begin tracking again. The basic frequency of the 566 function generator is controlled by a resistor capacitor combination. An FET exhibits the properties of a voltage controlled resistance with a very high input impedance. The gate voltage controls the drain to source resistance.

The circuit design is fairly simple; see Figure 15. The input will be the output of the tone decoder where signal present represents a zero level. The tone decoder output is then integrated starting at 4.3 volts. At the end of a mark the 2N708 is turned on, returning the output of the integrator to zero. The highest value of the integrated voltage is held by the 2µf capacitor. The voltage will leak off extremely slowly due to the almost infinite input impedance of the FET. The FET's drain and source replace those of the resistance in the 566 circuit. The correct slope as well as the correct voltage levels were determined from Figures 16 and 17. From Figure 16 it can be seen that the dash lengths vary from one hundred to four hundred twenty msec for thirty to ten wpm respectively. From Figure 17 it is noted that for this range of code speeds the gate voltage on the FET must vary between 5.8 and 4.7 volts. Simple geometry indicates that the start of integration must occur at 4.3 volts.

A very high impedance switch must be connected to the 2µf capacitor to discharge it when a new calibration is necessary.



AUTOMATIC CALIBRATION CIRCUIT

FIG-15

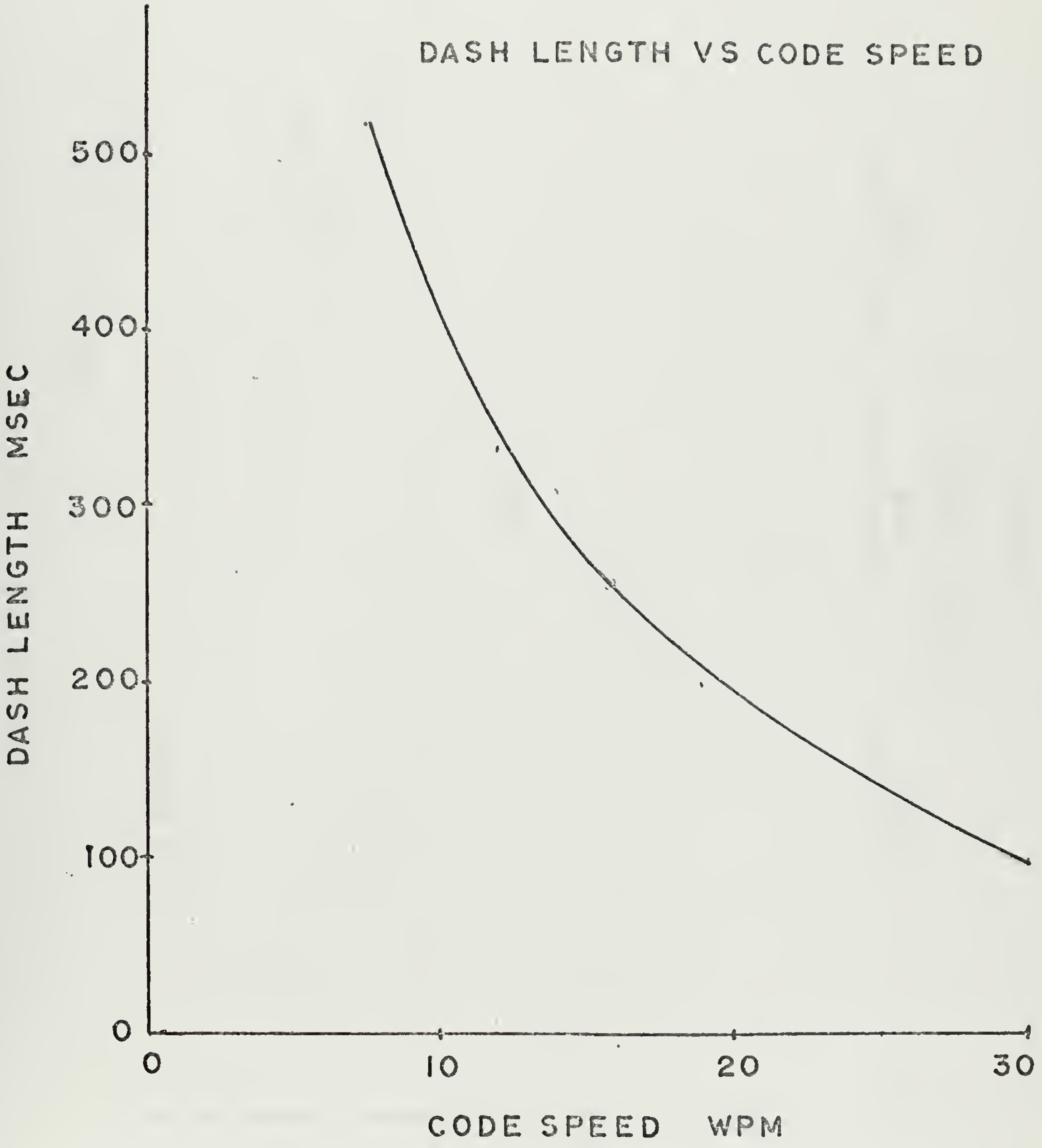
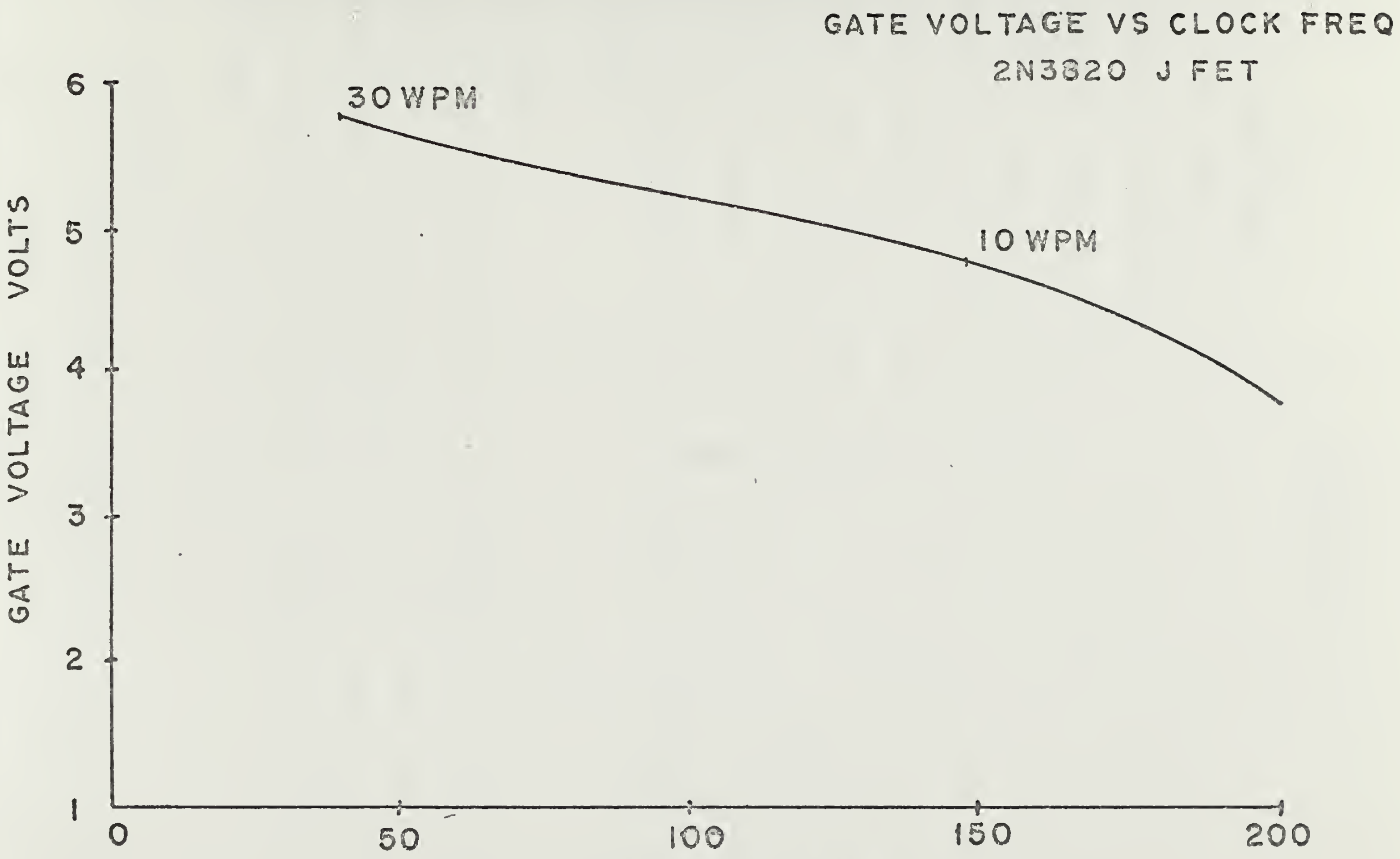

DASH LENGTH VS CODE SPEED
DASH LENGTH MSEC
500
400
300
200
100
0
0
10
20
30
CODE SPEED WPM

FIG-16



GATE VOLTAGE VS CLOCK FREQ
2N3820 J FET

FIG-17

VI. CONCLUSIONS

A. LIMITATIONS

This device will solve many of the problems of the automatic translating and transcribing of manual morse. It has a small limitation as to the range it will automatically track variations in sending speed. The machine will miss several characters when the code speed changes instantaneously. If there are two signals in the pass band of the tone decoder and both exceed the minimum detectable signal then the machine will be unable to distinguish between the two. If the transmitter drifts out of the pass band of the tone decoder it will have to be retuned.

B. COST

In the construction of the machine up to the LED display the cost was relatively low. The total cost was estimated to be approximately $100.00. This included the IC's, transistors, resistors, 7 printed circuit boards, 20 LEDs.

C. SUMMATION

At worst the machine could take the place of operators which are no longer present. It is also felt that the machine could assume the duties of very routine traffic

such as machine sent morse. It could also take the place of several operators translating hand sent morse and free them to take care of traffic where the machine is limited.

With the state of the art of integrated circuits of the LSI category this device could be made very small and efficient.

With refinement this machine could be the first step to filling the gap between the manpower shortage and maintaining of the effectiveness of operations.

BIBLIOGRAPHY

1. Blair, Charles R., "On Computer Transcription of Manual Morse," _Journal of the Association of Computing Machinery_, v. 6, no. 3, p. 433-434, July 1959.

2. Gonzales, C. and Vogler, R., "Automatic Radio Telegraph Translator and Transcriber," _Ham Radio_, p. 8-19, November 1971.

3. Selfridge and Neisser, "Pattern Recognition," _Scientific American_, August 1960.

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The problem of translating and transcribing manual more automatically had been considered as early as 1958. The construction, evaluation, and subsequent modification of just such a device is considered here.

The nature of the problem is discussed including the basic detection problem encountered with manual morse. An explanation of the theory of operation of the device follows with a

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block diagram and a short description of each block. The third section discusses the tests, evaluation and modifications including operation in the minimum signal to noise ratio and code speed tracking capability. Areas for further development are next considered which include an automatic recalibration scheme and the use of "read only memories" in the decoding section. The conclusions make up the last section which considers the effectiveness, costs and limitations.

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